

# Heliospheric Tomography - Results Using 3-D MHD Kernels

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# Heliospheric Tomography - Results Using 3-D MHD Kernels

## Introduction:

**IPS time-dependent **kinematic model** analysis:**  
**A worldwide operation that includes magnetic field.**

**IPS-iterated 3-D MHD:**

**The 3-D MHD models iteratively fit to IPS observations.**

**What's Next?**

An **Ensemble Model (ENLIL with Cone Updated by IPS)**

**WIPSS (Worldwide InterPlanetary Scintillation Stations) network**

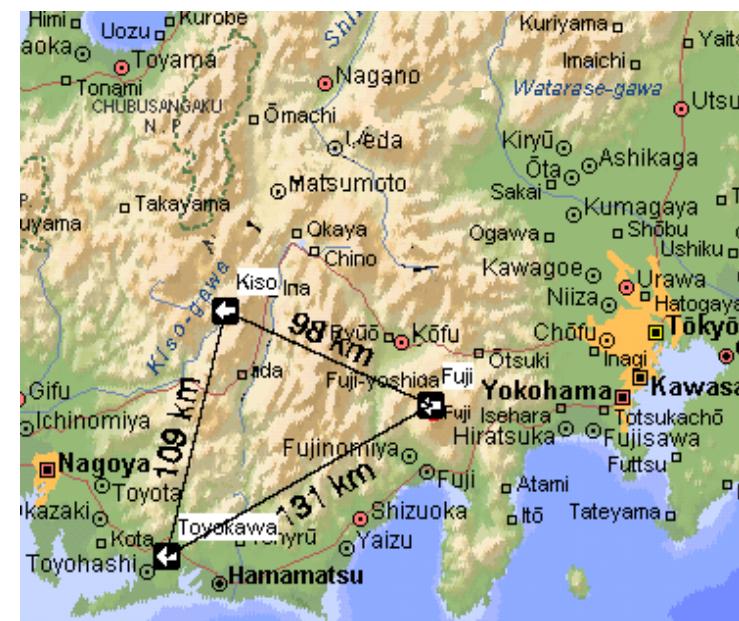
# Heliospheric Tomography - Results Using 3-D MHD Kernels

## DATA

### IPS Heliospheric Analyses at ISEE (STELab)



ISEE IPS array system  
327 MHz ~2600 m<sup>2</sup>

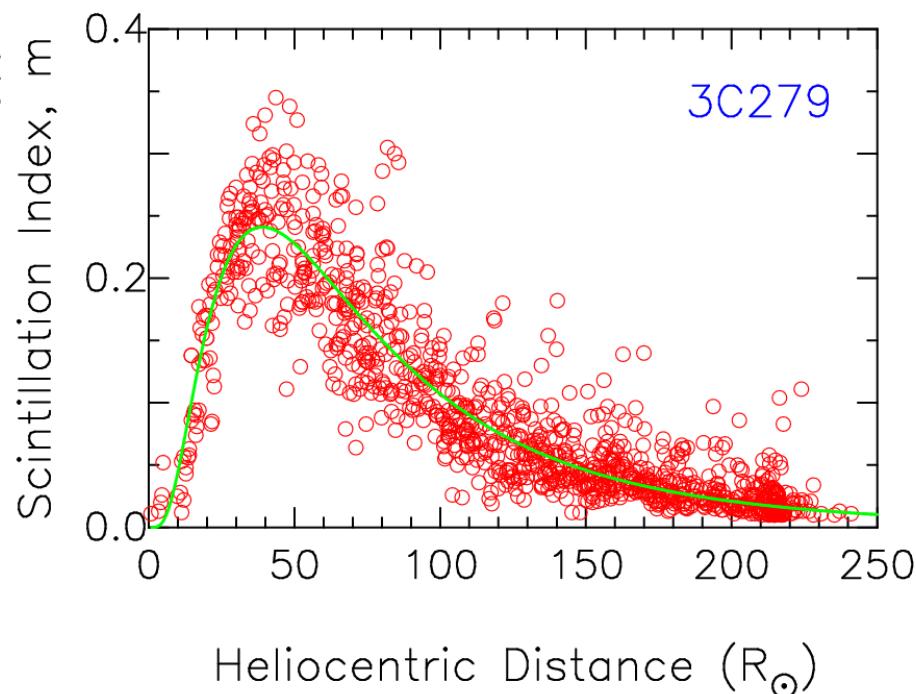
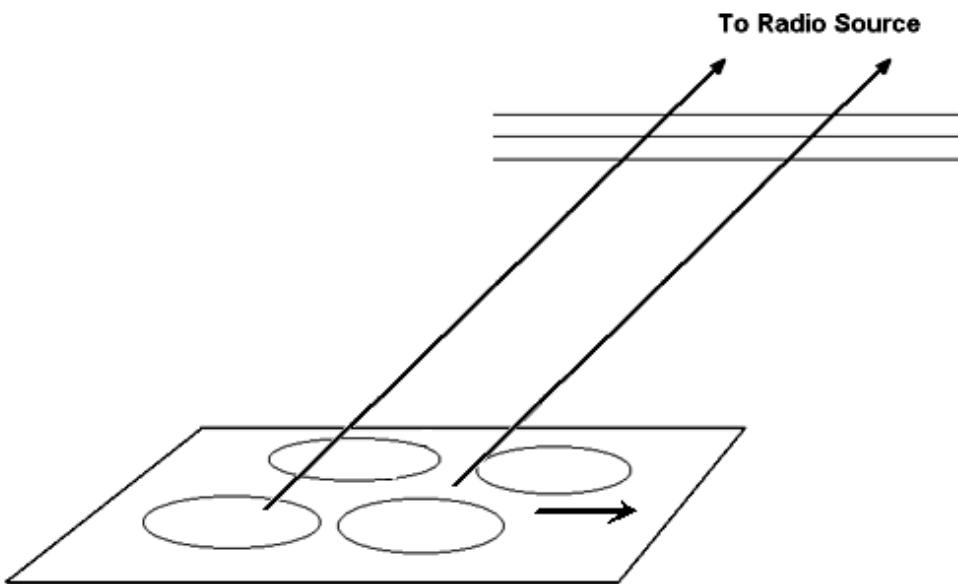


ISEE IPS array systems

# Heliospheric Tomography - Results Using 3-D MHD Kernels

## DATA

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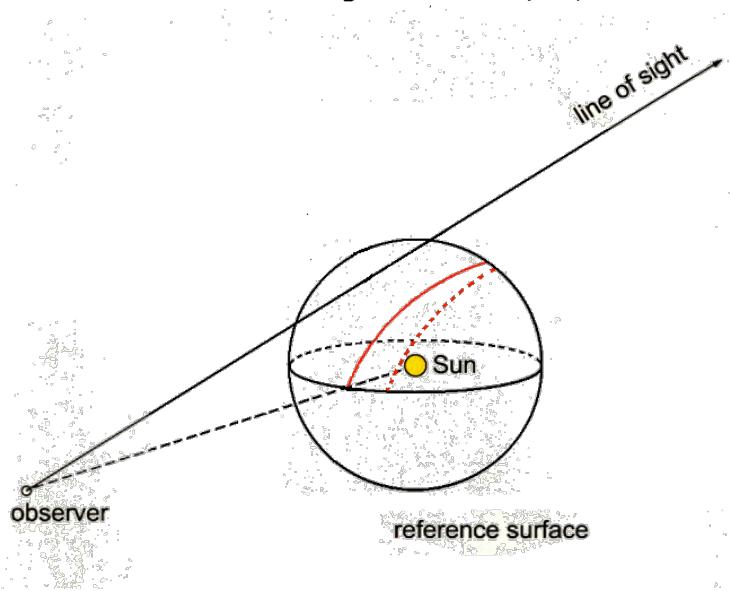
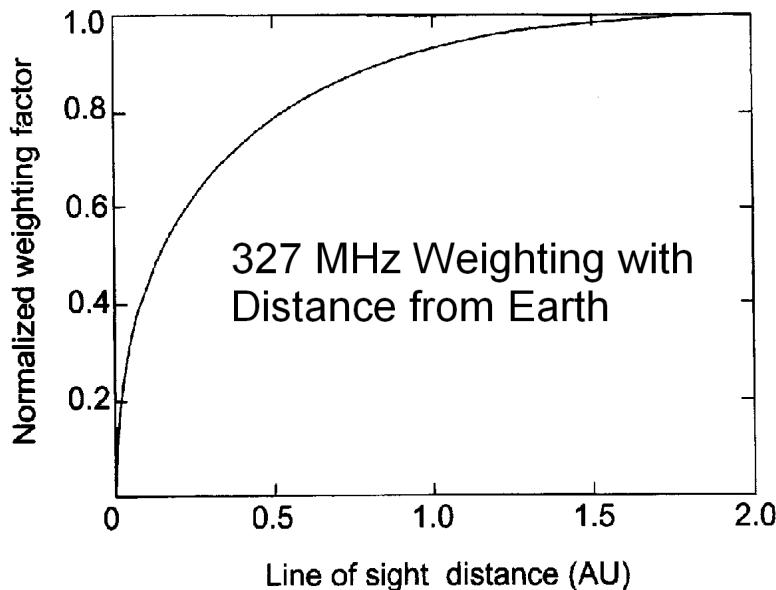


ISEE IPS array systems

# Heliospheric Tomography - Results Using 3-D MHD Kernels

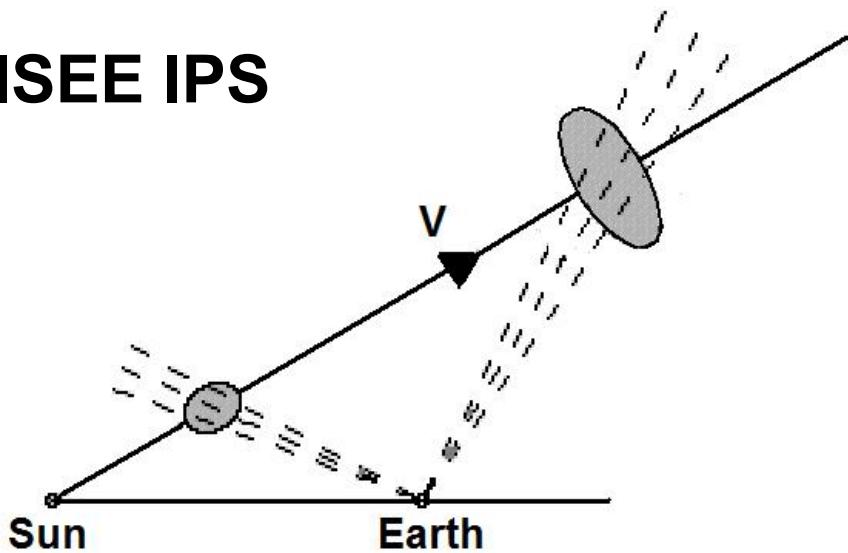
## IPS line-of-sight response

Jackson, B.V., et al., 2008, *Adv. in Geosciences*, 21, 339-360.



**Heliospheric C.A.T. analyses:**  
example line-of-sight distribution  
for each sky location to form the  
source surface of the 3-D  
reconstruction.

## ISEE IPS

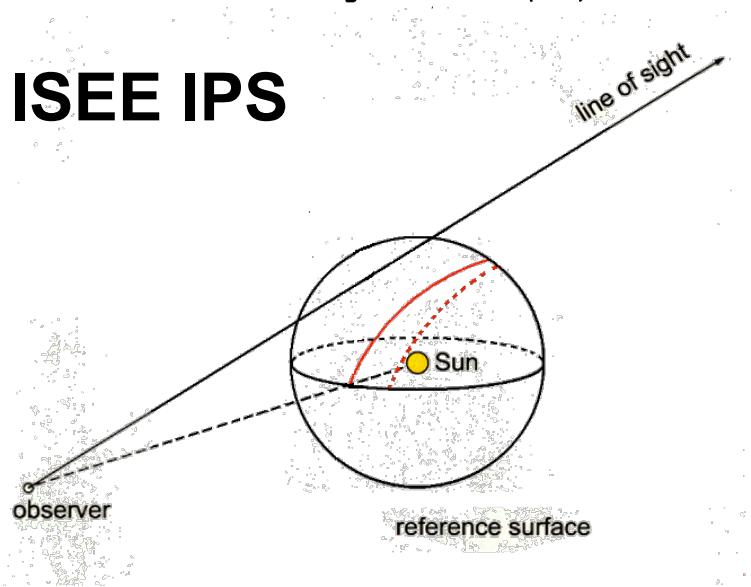
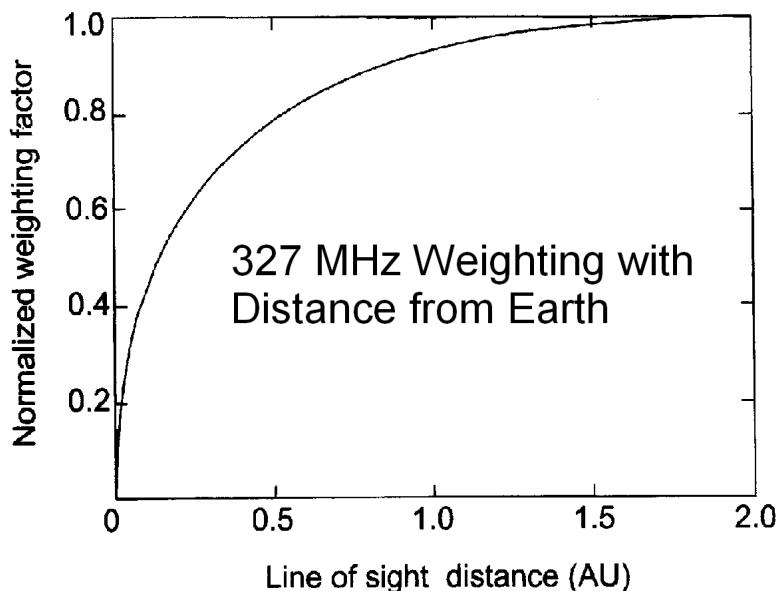


Sample outward motion  
over time

# Heliospheric Tomography - Results Using 3-D MHD Kernels

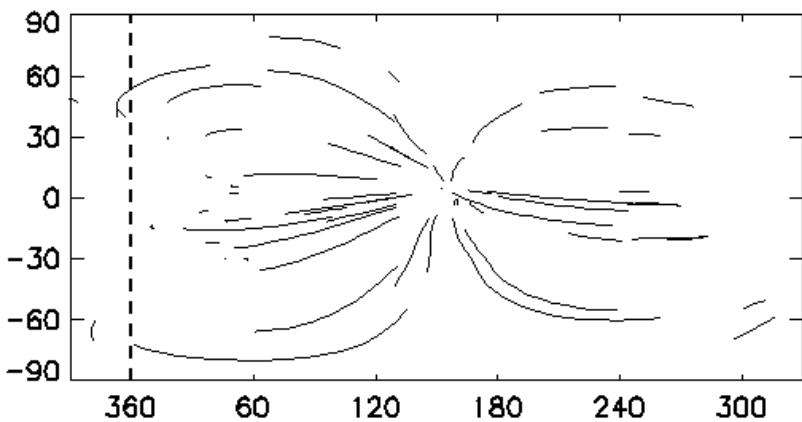
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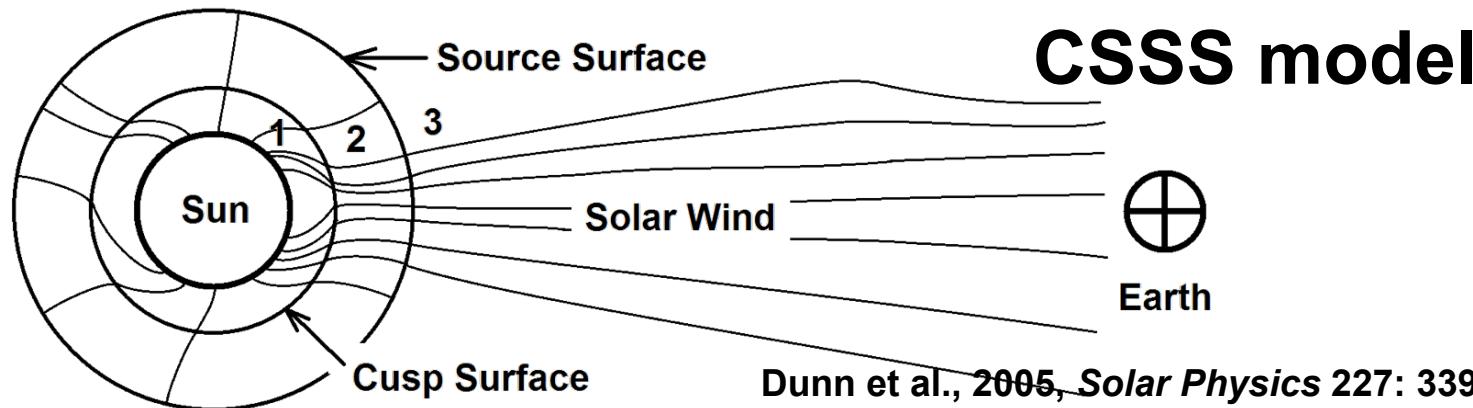
## ISEE Lower Surface Boundary



14 July 2000

# Heliospheric Tomography - Results Using 3-D MHD Kernels

(Zhao, X. P. and Hoeksema, J. T., 1995, *J. Geophys. Res.*, 100 (A1), 19.)

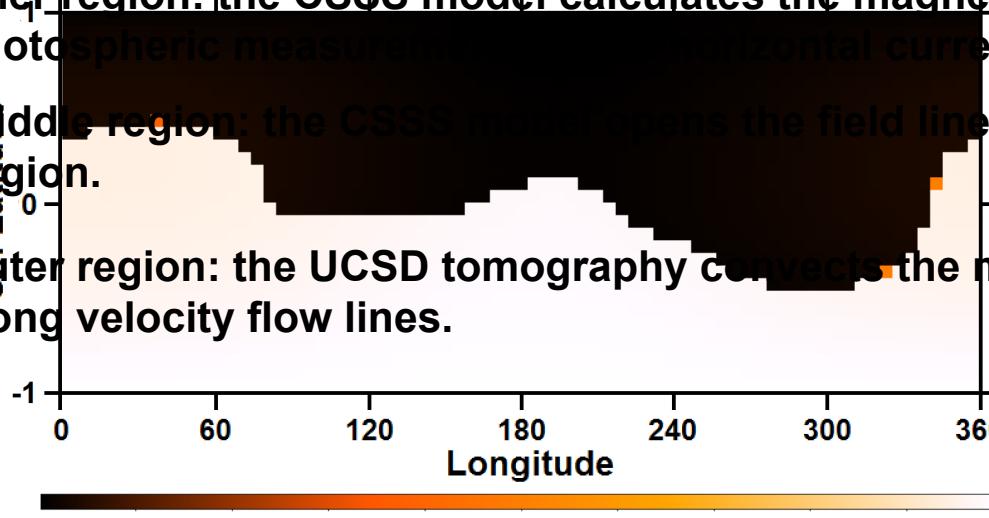


Dunn et al., 2005, *Solar Physics* 227: 339–353.



## Source surface (15 Rs) $B_r$ field component sample

1. Inner region: the CSSS model calculates the magnetic field using photospheric measurements and a horizontal current model.
2. Middle region: the CSSS model opens the field lines. In the outer region.
3. Outer region: the UCSD tomography convects the magnetic field along velocity flow lines.



## Real-Time Kinematic Model

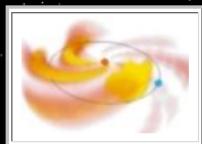
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Jackson, B.V., et al., 2011, *Adv. in Geosciences*, 30, 93-115.

<http://ips.ucsd.edu/> or [http://ips.ucsd.edu/high\\_resolution\\_predictions](http://ips.ucsd.edu/high_resolution_predictions)

## UCSD Prediction Analyses

The screenshot shows a web browser window with the URL [ips.ucsd.edu](http://ips.ucsd.edu) in the address bar. The page content is titled "Space Weather Forecasting Velocity and Density Plots with Interplanetary Scintillation Data". It features a large, colorful contour plot of space weather parameters, with two specific points marked by circles (one red, one blue) and connected by a line. The top right of the page includes the logos for CASS (Center for Astrophysics & Space Sciences) and ISSE (Institute for Space-Earth Environmental Research). On the left side, there is a sidebar with various links related to space weather predictions and data archives.

23:03:00 UTC  
12-Mar-2018  


[High Resolution Predictions](#)  
[IPS Data Archive](#)  
[IPS Workshop 2016](#)  
[Space Weather Links](#)  
[Public Introduction](#)  
[Science Introduction](#)  
[Solar System Space Weather](#)

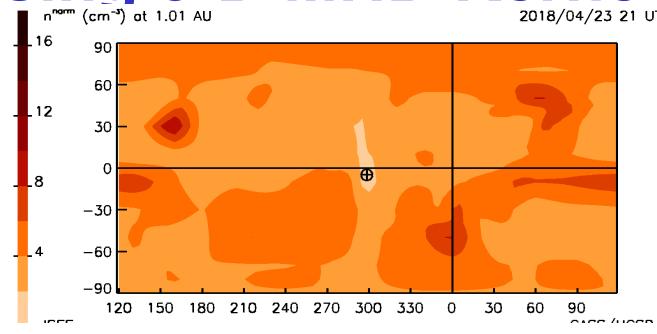
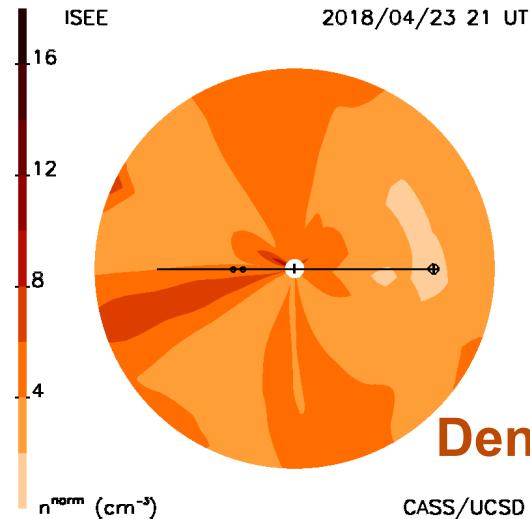
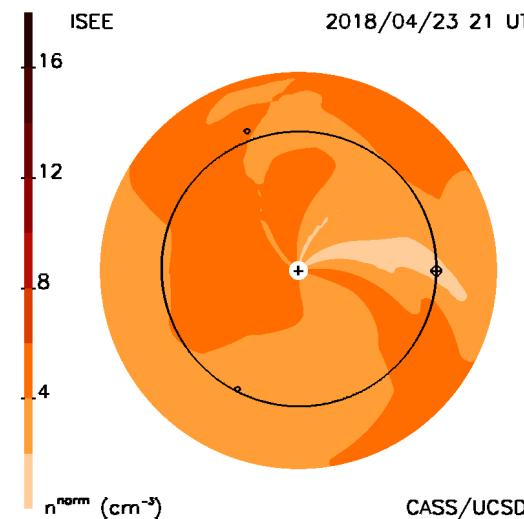
**Time-Dependent**  
[Remoteview](#)  
[Synoptic Map](#)  
[Sky Map](#)  
[Sky Sweep](#)  
[Ecliptic Cut](#)  
[Time Series](#)  
[Correlations](#)

Transferring data from ips.ucsd.edu...

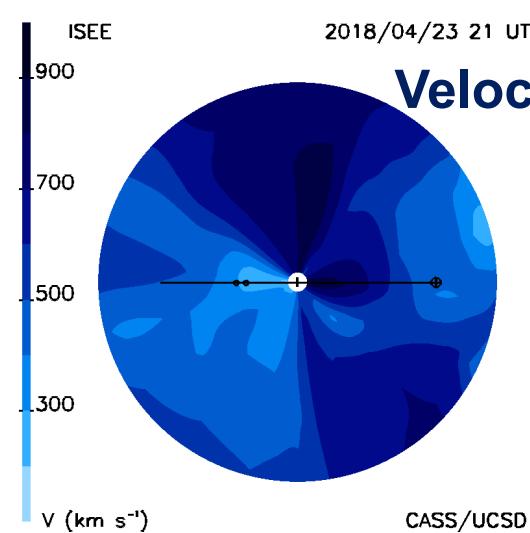
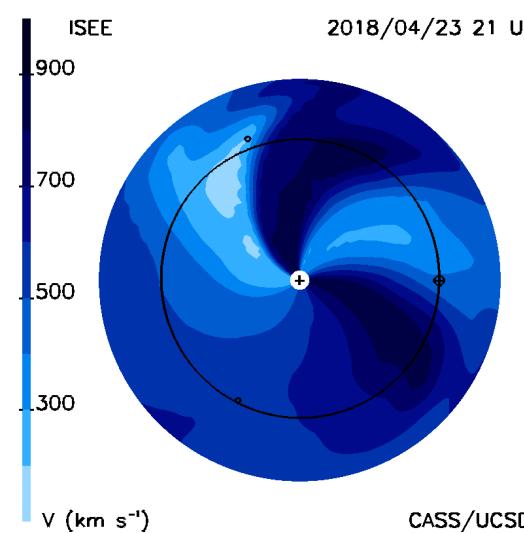
Web analysis runs “automatically” using Linux on a P.C.

# Heliospheric Tomography - Results Using 3-D MHD Kernels

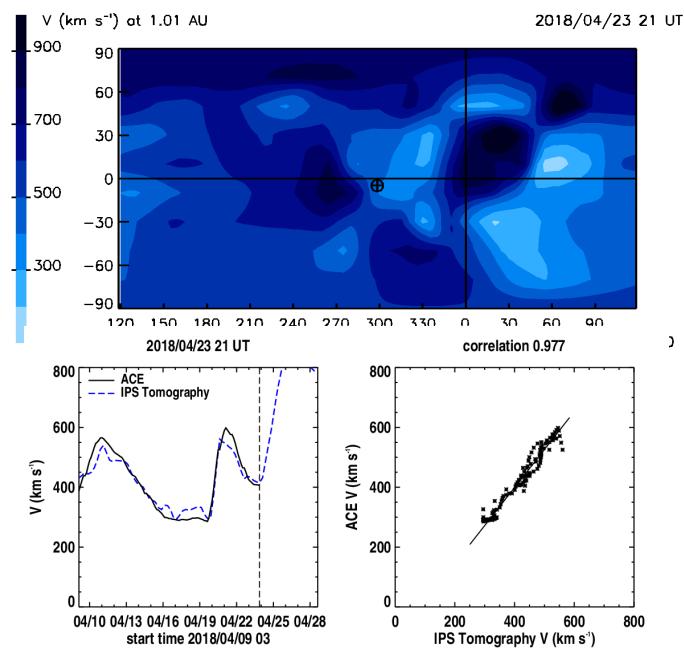
## Last Night 2018/04/23 21UT



Density



Velocity



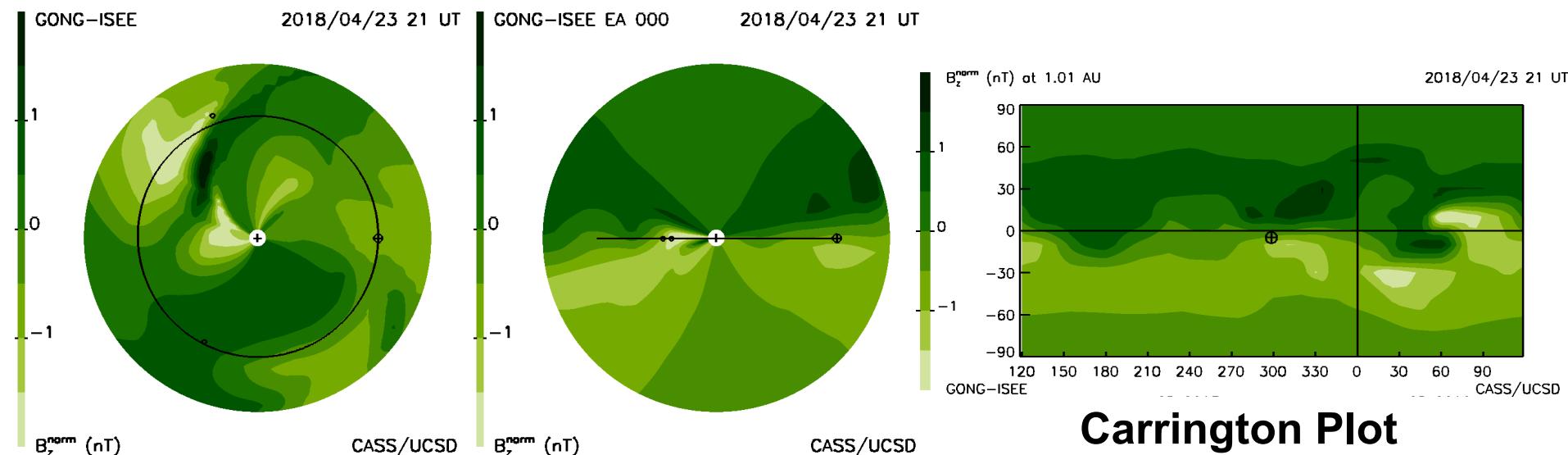
Ecliptic Cuts

Meridional Cuts

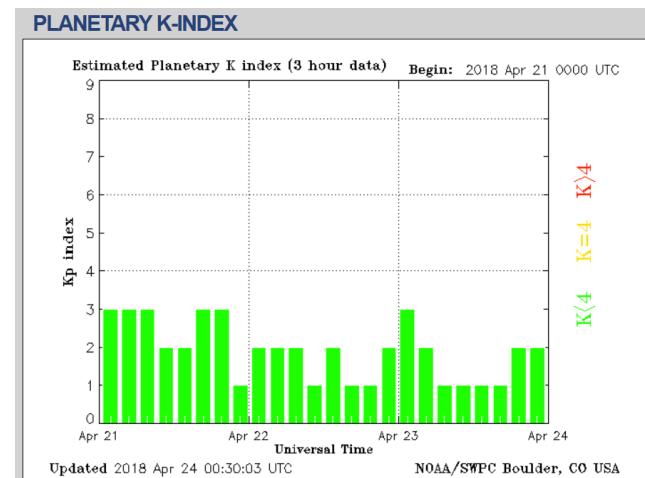
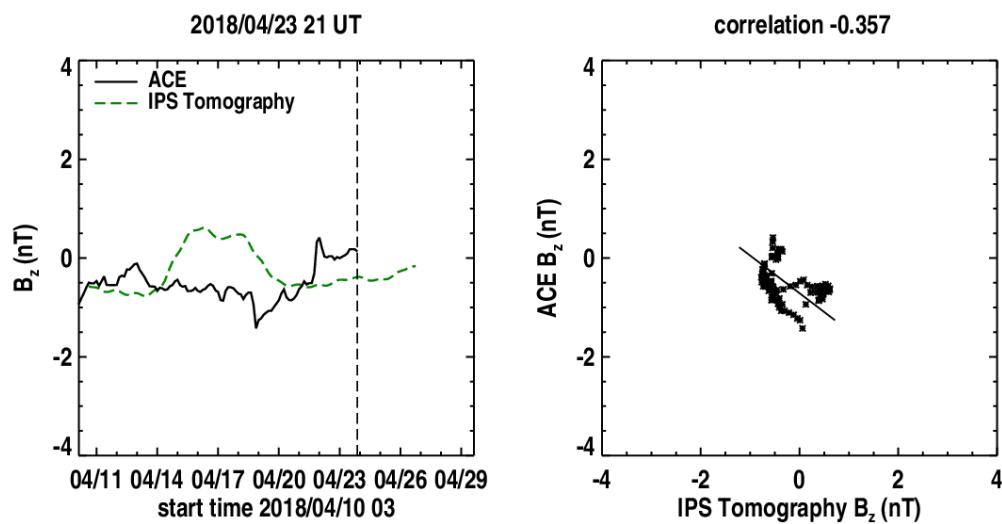
# Heliospheric Tomography - Results Using 3-D MHD Kernels

Last Night 2018/04/23 21UT

GSM Bz



Carrington Plot

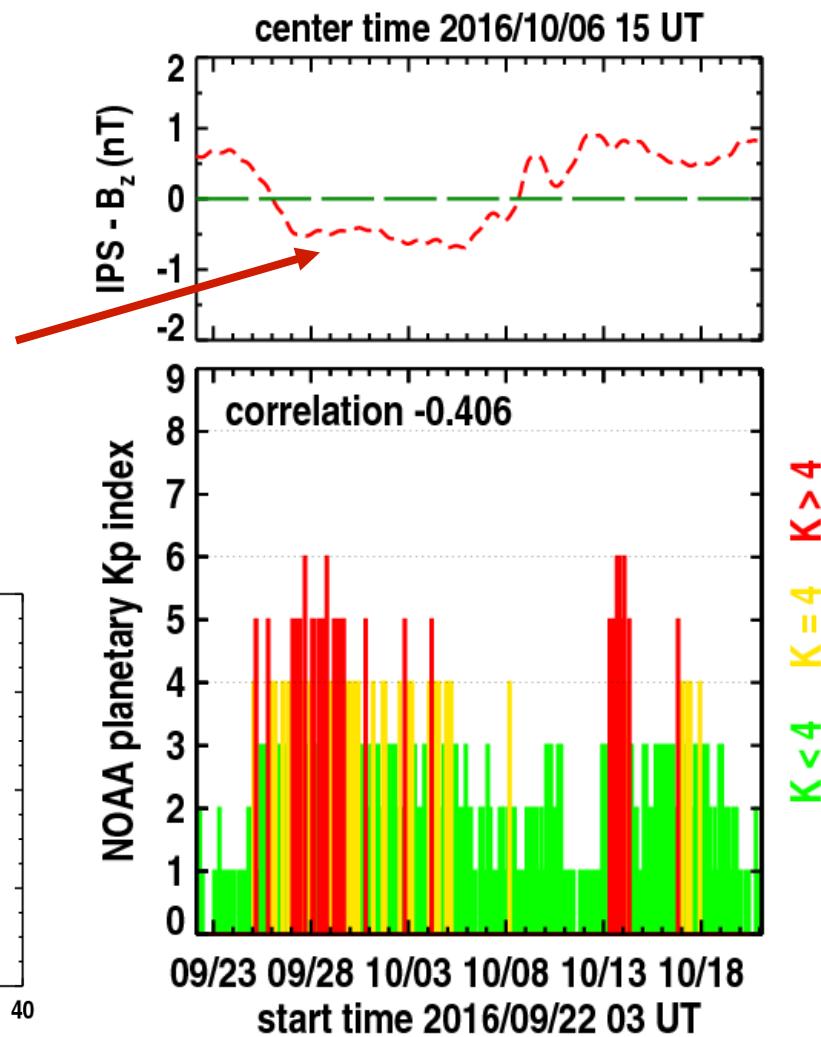
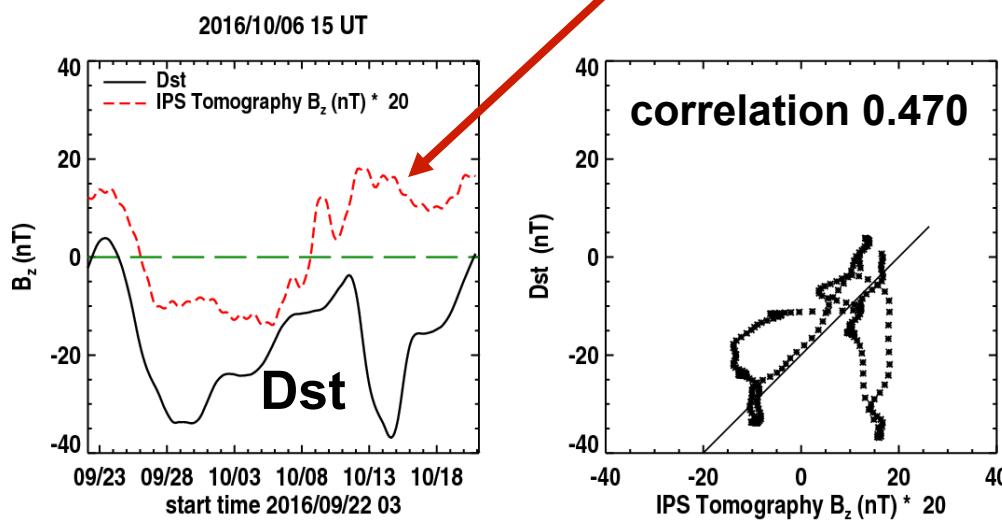


NOAA Kp Index

# Heliospheric Tomography - Results Using 3-D MHD Kernels

CR2182.0 2016 09/22-10/21 GSM Bz

Sample correlations  
for CR2182 between  
the tomography-  
derived Bz  
and Dst or Kp



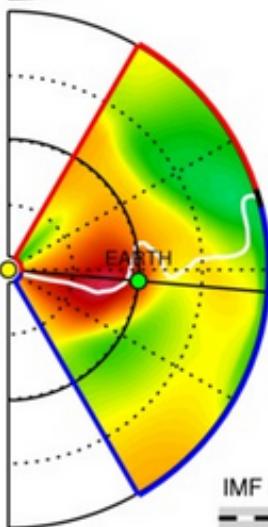
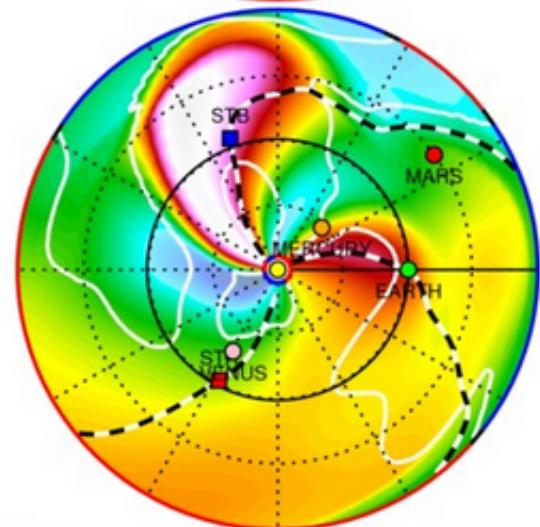
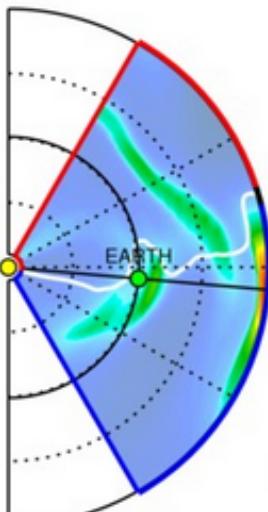
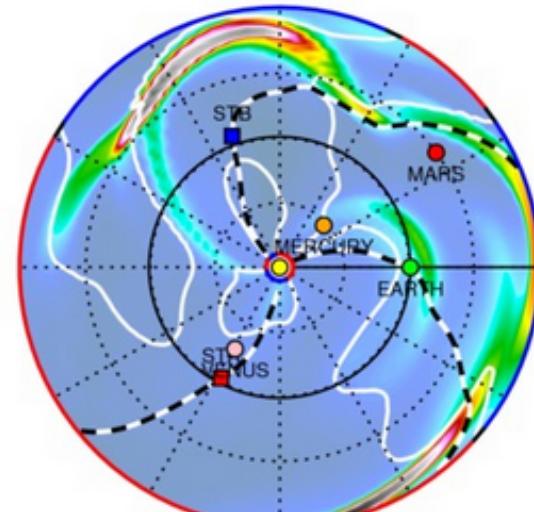
# **Heliospheric Tomography - Results Using 3-D MHD Kernels**

**Real-Time IPS - Driven ENLIL**

# Heliospheric Tomography - Results Using 3-D MHD Kernels

## Last Night IPS Prediction (KSWC)

<http://www.spaceweather.go.kr/models/ipsbdenlil>



2018-04-23T19:00

2018-04-23T19 + 0.00 days

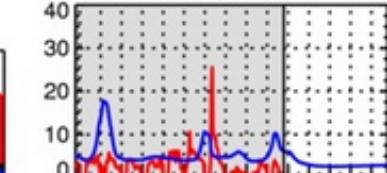
Normalized Solar Wind Number Density  
 $R^2 N$  (cm<sup>-3</sup>)  
0 10 20 30 40 50 60

Solar Wind Radial Velocity  
 $V_r$  (km/s)  
200 400 600 800 1000 1200 1400 1600

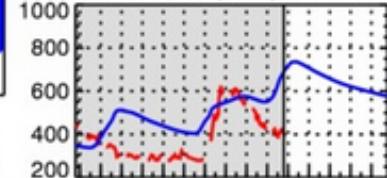
IMF line      IMF polarity      HCS

Profiles at EARTH

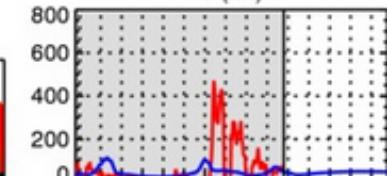
$N$  (cm<sup>-3</sup>)



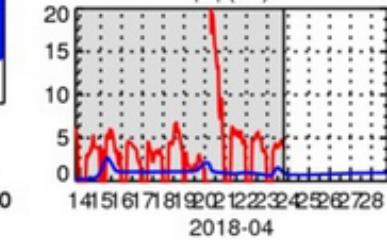
$V_r$  (km/s)



$T$  (kK)



$|B|$  (nT)



measured      simulated

HelioWeather @ KSWC

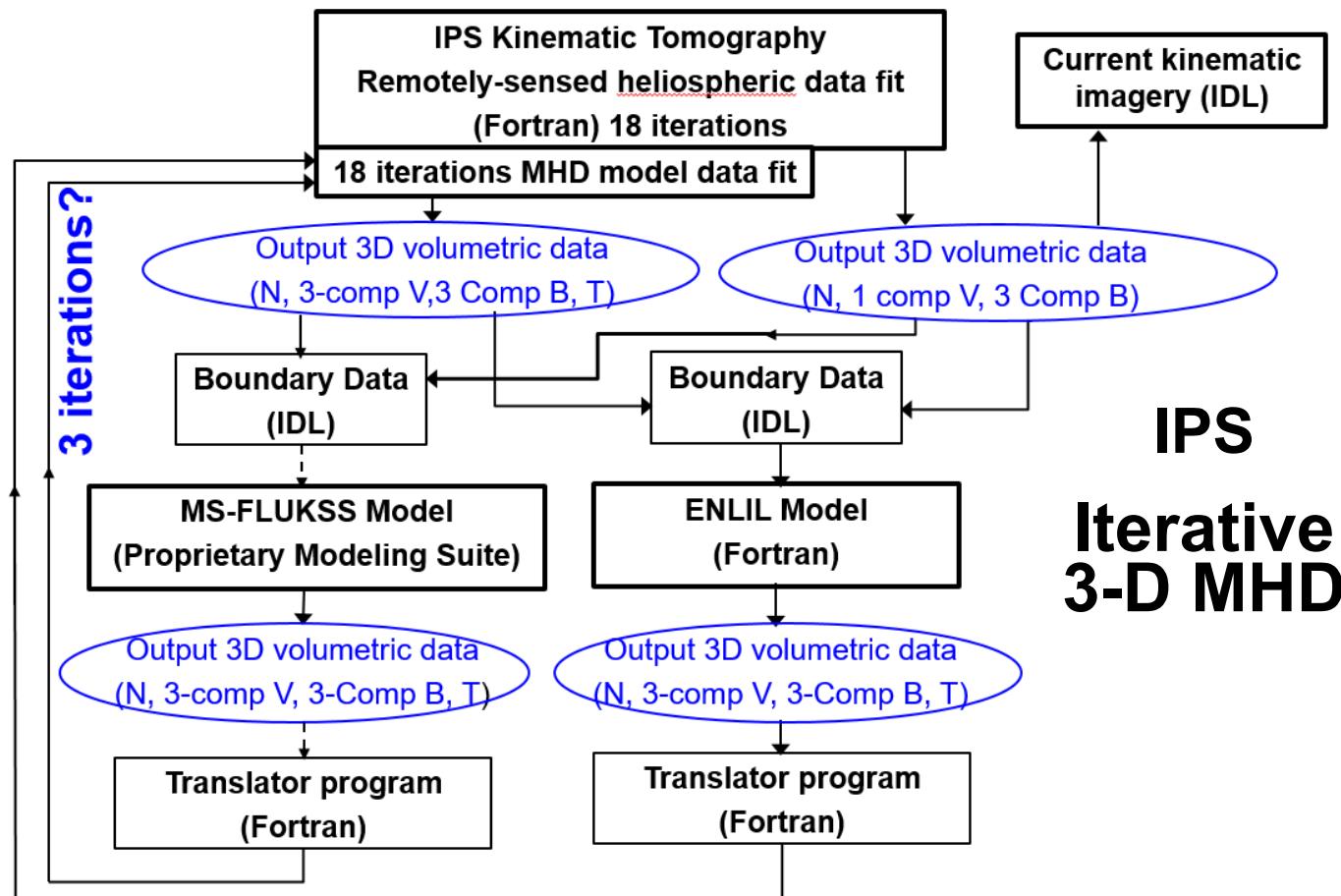
# IPS-Driven ENLIL

# Heliospheric Tomography - Results Using 3-D MHD Kernels

**IPS Iteratively - Updated 3-D MHD**

# Heliospheric Tomography - Results Using 3-D MHD Kernels

## The Iterative Process with 3-D MHD models



**UHA MS-FLUKSS  
(Pogorelov)**

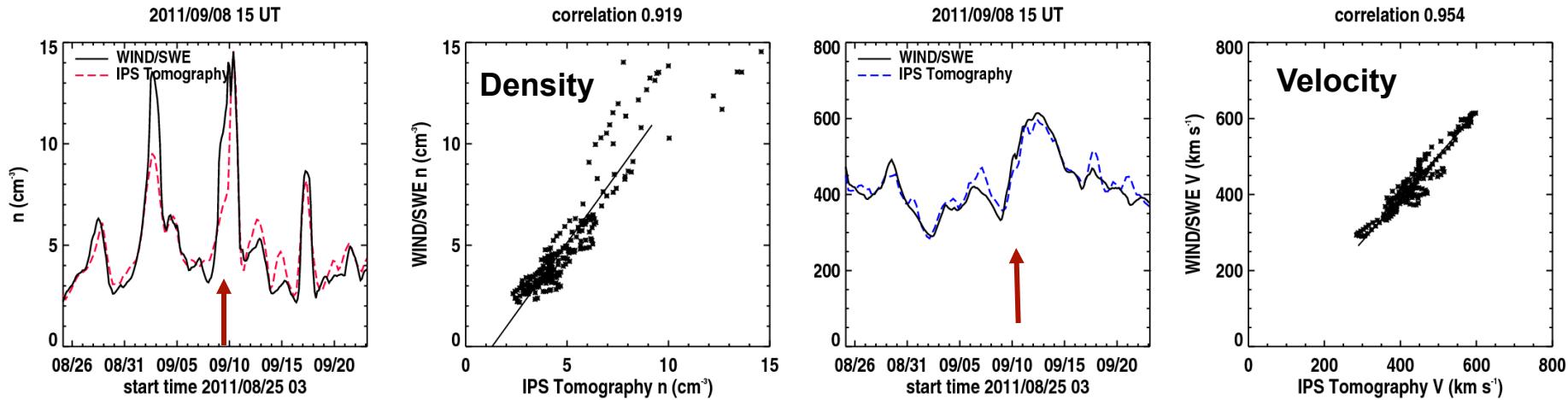
**ENLIL  
(Odstrcil)**

# Heliospheric Tomography - Results Using 3-D MHD Kernels

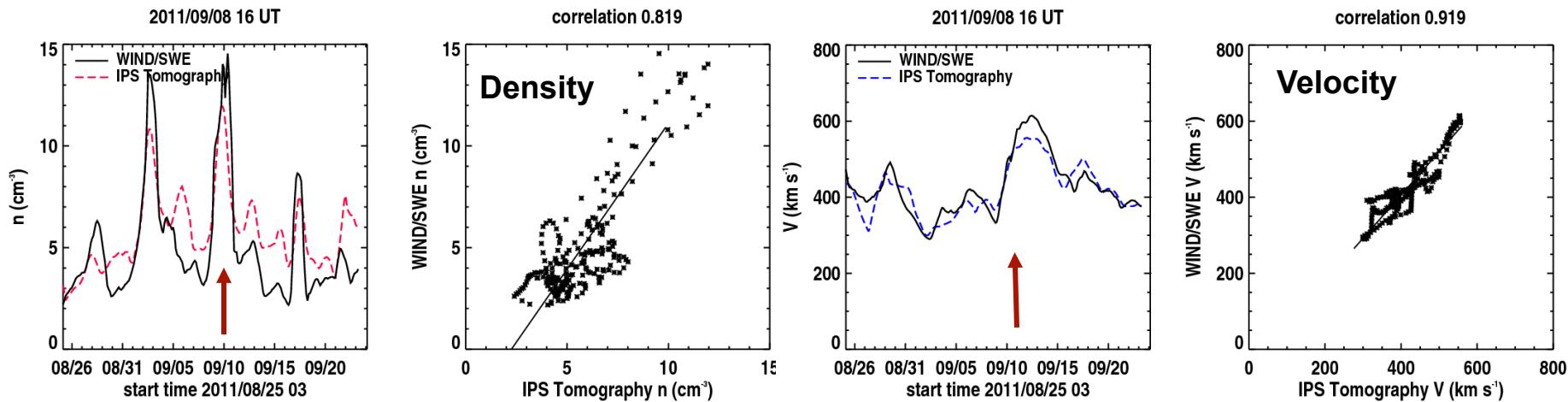
## IPS Iteratively Updated ENLIL Model Density/Velocity

### CR2114.0 (2011/09/10 03 UT CME at Earth)

#### Iteration 0 (Kinematic - IPS)



#### Iteration 2 (ENLIL - IPS)

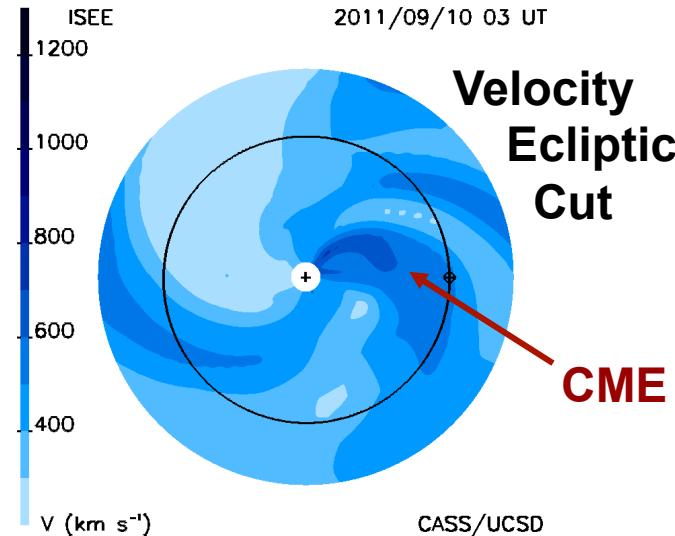
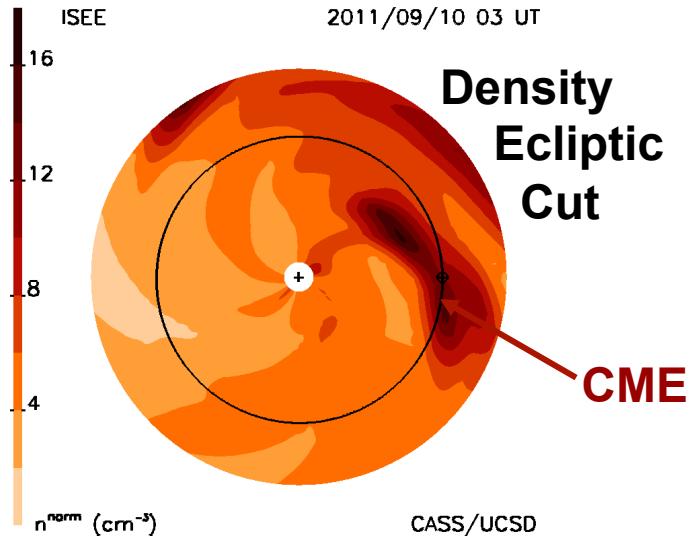


# Heliospheric Tomography - Results Using 3-D MHD Kernels

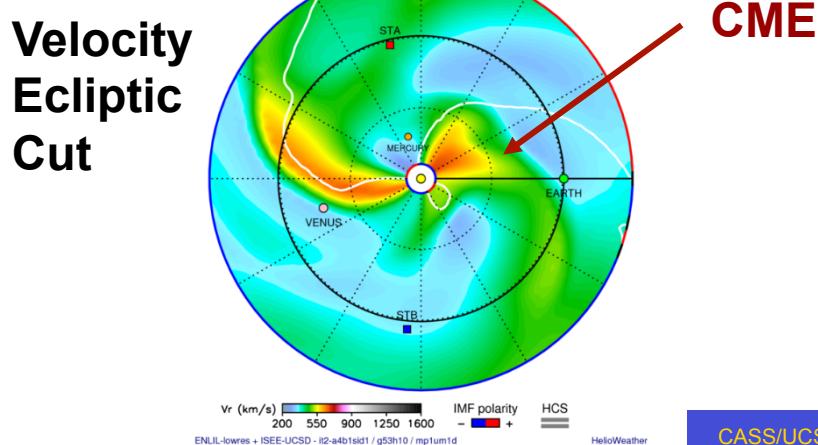
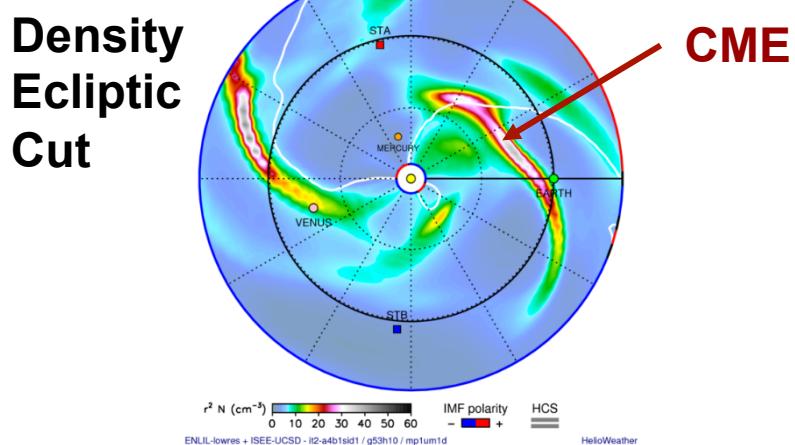
## IPS Iteratively Updated ENLIL Model Density/Velocity

2011/09/10 03 UT CME at Earth

Iteration 0 (Kinematic - IPS)



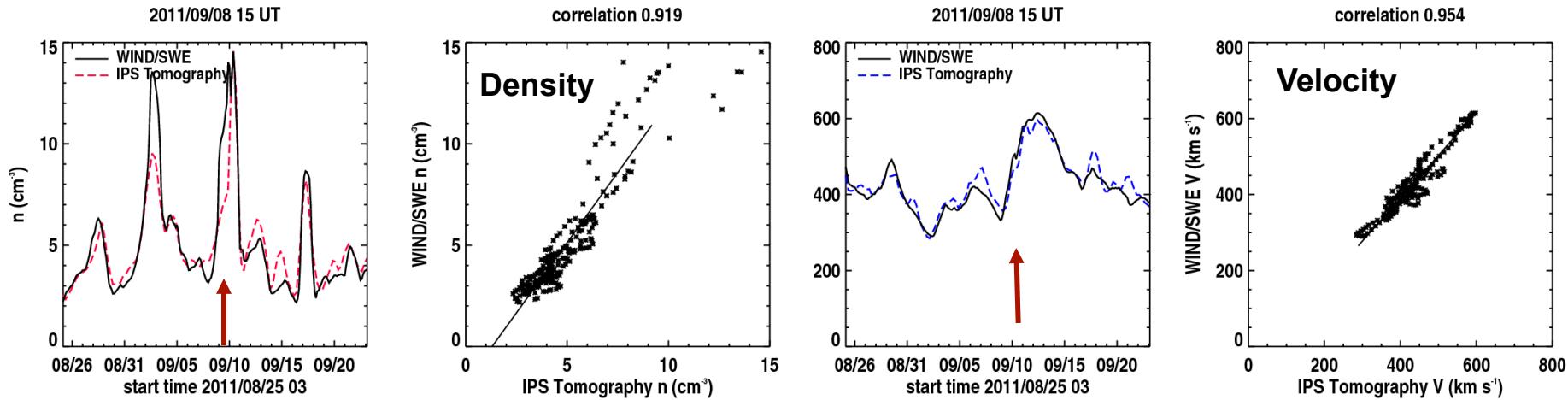
Iteration 2 (ENLIL - IPS)



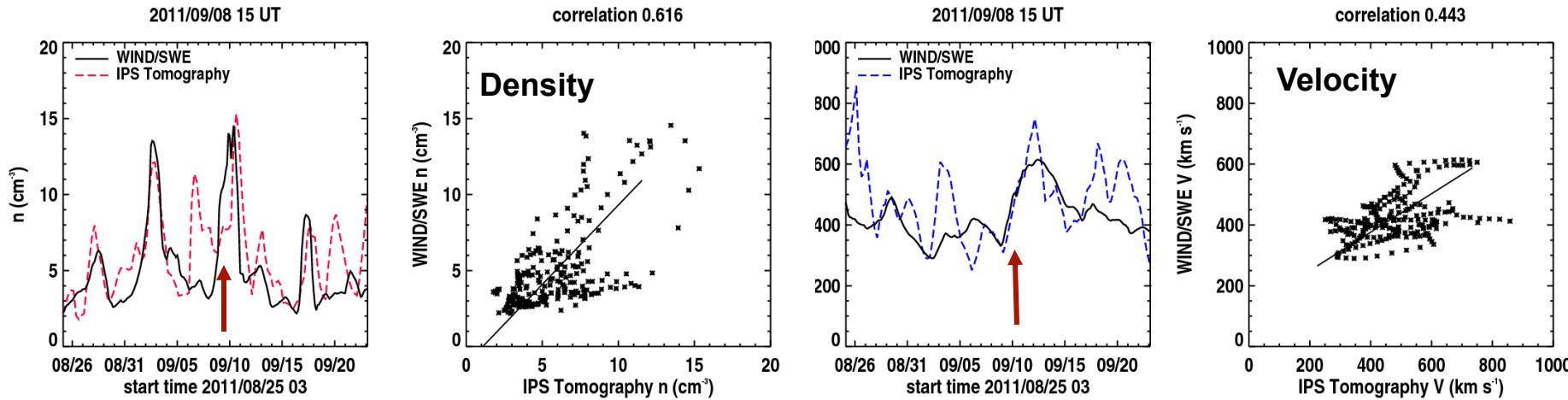
# Heliospheric Tomography - Results Using 3-D MHD Kernels

## IPS Iteratively Updated MS-FLUKSS Density/Velocity CR2114.0 (2011/09/10 03 UT CME at Earth)

### Iteration 0 (Kinematic - IPS)



### Iteration 3 (MS-FLUKSS - IPS)

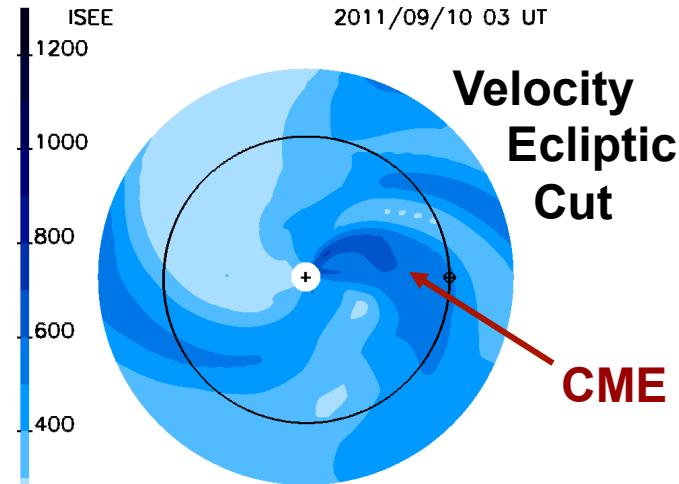
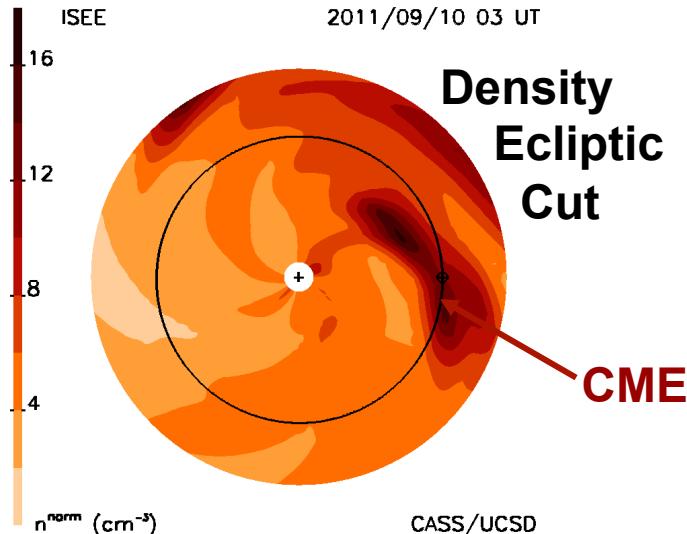


# Heliospheric Tomography - Results Using 3-D MHD Kernels

## IPS Iteratively Updated MS-FLUKSS Density/Velocity

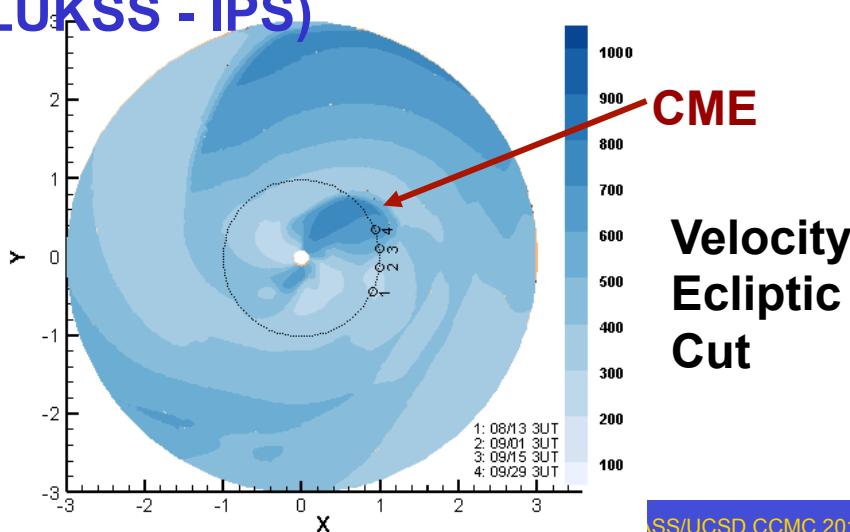
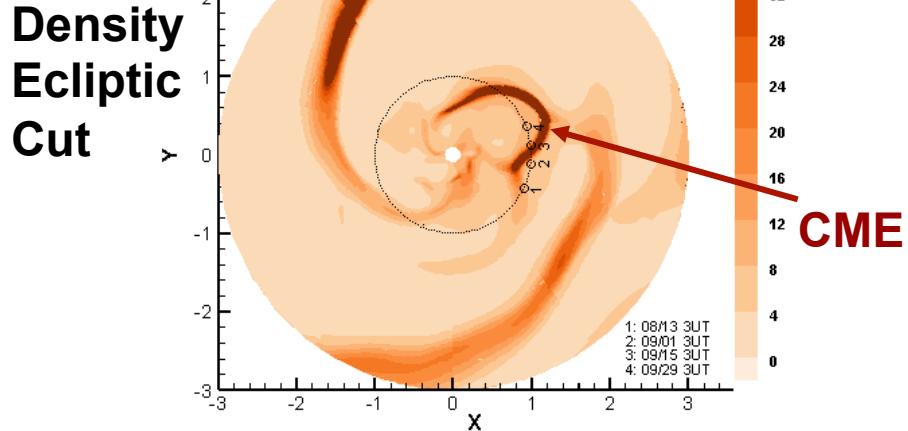
2011/09/10 03 UT CME

Iteration 0 (Kinematic - IPS)



CASS/UCSD

Iteration 3 (MS-FLUKSS - IPS)



# **Heliospheric Tomography - Results Using 3-D MHD Kernels**

## **So now that we have this technique, what can we do with it?**

- 1) Compare 3-D MHD models and determine their differences  
not only in-situ, but at the lower boundary and in between.**
- 2) Explore the non-radial heliospheric transport of  
various solar structures.**
- 3) Compare the 3-D structure of poorly-known parameters  
(density, velocity) in the heliosphere with observed  
coronal features.**
- 4) Explore the now-assumed and poorly-known model  
values (heating, gamma) provided in 3-D MHD models.**
- 5) Better space weather predictions.**

# Heliospheric Tomography - Results Using 3-D MHD Kernels

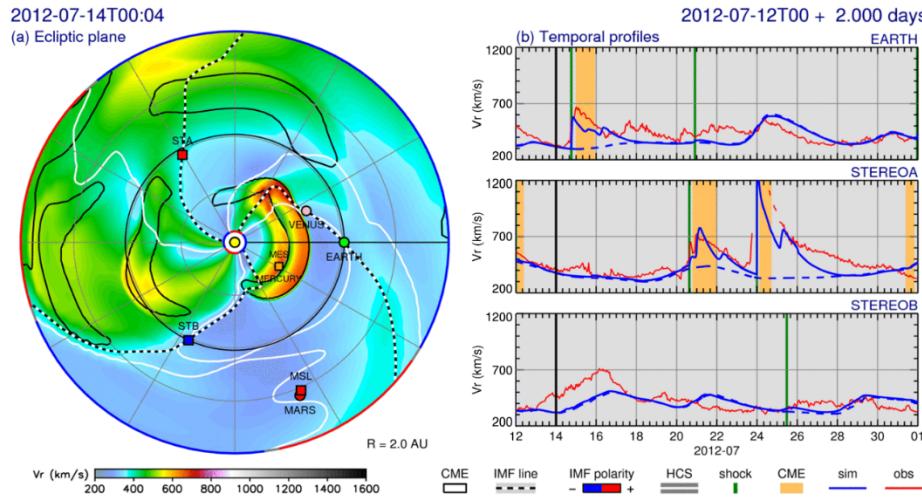
## Next

**IPS - Updated 3-D ENLIL  
with Cone**

# Heliospheric Tomography - Results Using 3-D MHD Kernels

# Next

# Ensemble Model



Update  
ENLIL with  
Cone by  
IPS

## Next

**Better IPS analysis?**

**A New Organization Name**

**WIPSS**

**(Worldwide InterPlanetary Scintillation  
Stations) Network**

# Heliospheric Tomography - Results Using 3-D MHD Kernels

## World-wide IPS stations network

Pushchino 103MHz  
70,000 m<sup>2</sup>



UK/EISCAT  
LOFAR)

STEL Multi-Station 327MHz  
2000 m<sup>2</sup> × 2, 3500 m<sup>2</sup>



Data

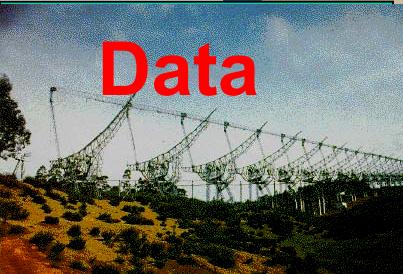
MEXART  
140MHz, 10,000 m<sup>2</sup>



Data

IPS

Data



Russia

Korea

India

Japan

Mexico

MWA  
80-300MHz

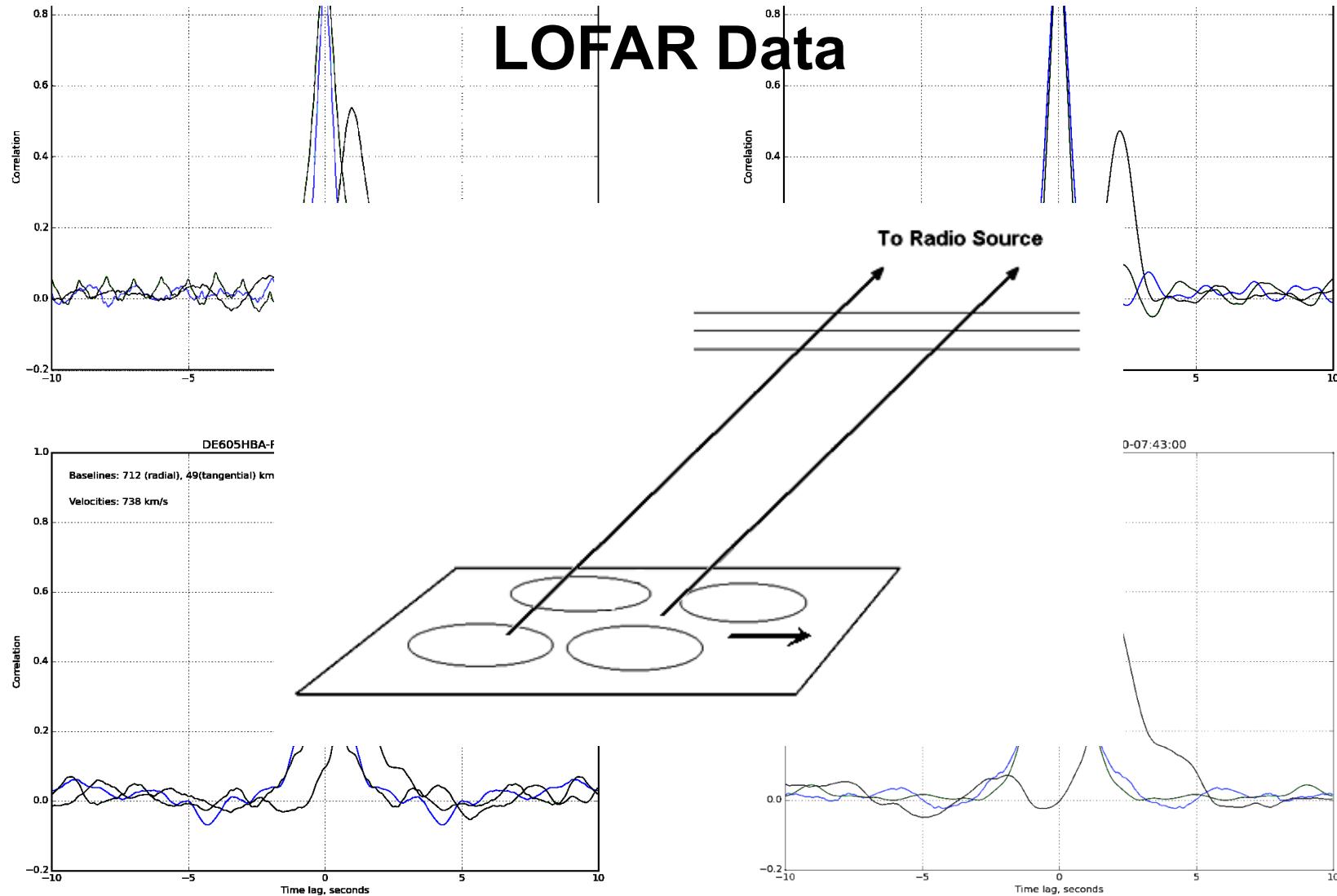
US-Australia



Ooty 327MHz, 16,000 m<sup>2</sup>

# Heliospheric Tomography - Results Using 3-D MHD Kernels

## Multi-Site Analysis for IPS systems for Velocity

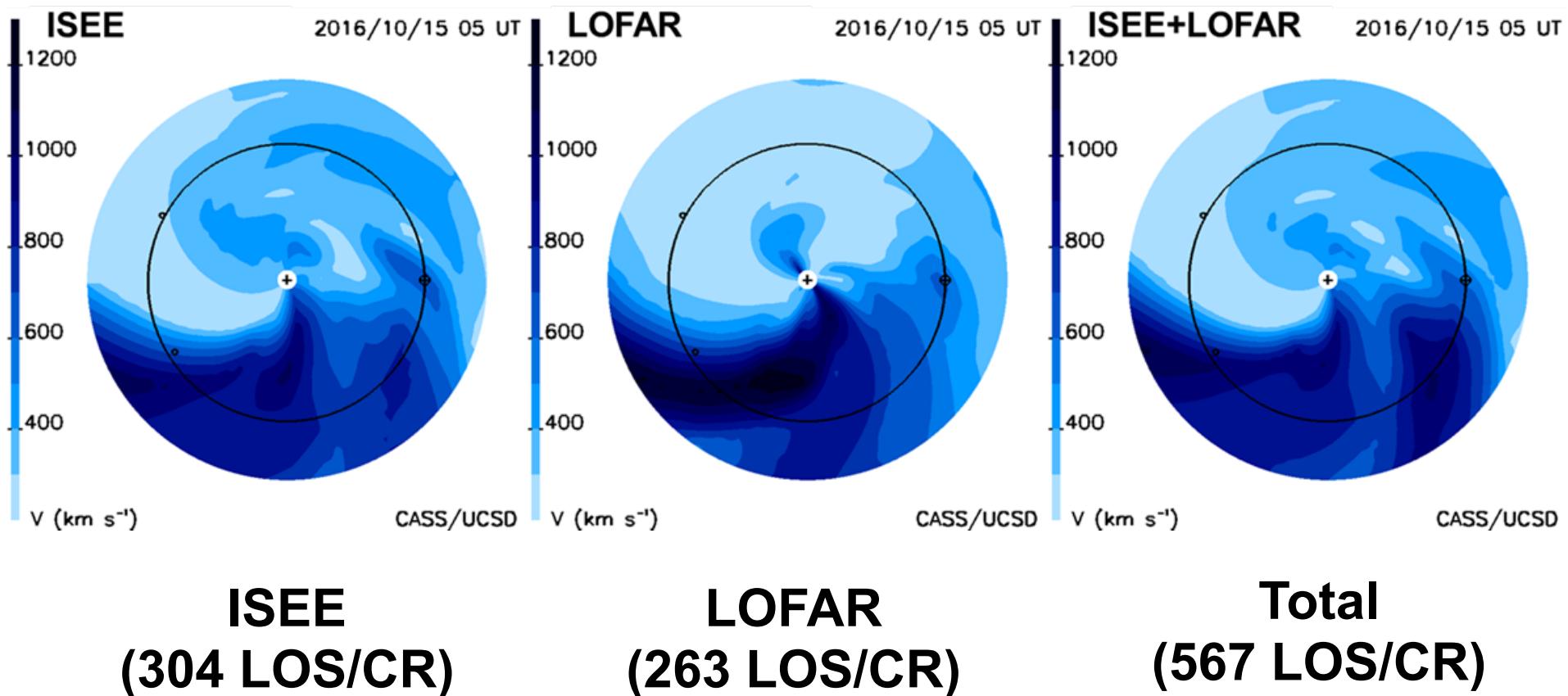


Courtesy Richard Fallows, ASTRON, The Netherlands

# Heliospheric Tomography - Results Using 3-D MHD Kernels

## Combination of IPS Station Analyses

### (October 2016 LOFAR Campaign)



LOFAR analysis, images, courtesy of M.M. Bisi, R. Fallows

# Heliospheric Tomography - Results Using 3-D MHD Kernels

## Conclusion:

**IPS time-dependent **kinematic model** analysis:**  
**A worldwide operation that includes magnetic field.**

**IPS-iterated 3-D MHD:**

**The 3-D MHD models iteratively fit to IPS observations.**

**What's Next?**

An **Ensemble Model (ENLIL with Cone Updated by IPS)**

**WIPSS (Worldwide InterPlanetary Scintillation Stations) network**